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The Evolution and Perfection of the Aseptic Surgical Technique.

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It is not purposed in this paper to trace every step in the origin and development of aseptic and antiseptic surgery, or to discuss the comparative merits of various germicidal agencies. The relation of micro-organisms to wound infection and the efficacy of aseptic and antiseptic methods in surgery have now passed beyond controversial limits and have reached the finality of absolute demonstration. Notwithstanding that a revolution has been wrought in surgery in consequence, much yet is needed to perfect the modern system of wound treatment. While the conditions underlying wound infection are generally understood and accepted, the technique observed by operative surgeons generally is not so thorough as to secure that precision and uniformity in results which theoretically should be obtained, and which undoubtedly is practicable. It seems that the present is a most opportune time for surgeons to review bacteriologic data and working methods based thereon, so as to eliminate all that is useless and superfluous in order to concentrate attention upon that which is absolutely essential.

The first definite and refined experimental data initiating modern ideas of wound treatment undoubtedly came from Pasteur, who demonstrated the relation of bacteria to fermentation and putrefaction, and thus suggested that the phenomena which occurred in wounds were due rather to the entrance of something from without than to some cause within. Pasteur showed that putrefaction was a fermentative process caused by the growth of microbes, and that these organisms do not arise

de novo in the decomposable substance, the germs abound in the air. Lister inaugurated a system of wound treatment founded upon these observations. The primal idea in Lister's mind originated in the common observation of the difference in the clinical course of simple and compound fractures.* It was most logical that he should have regarded the air as the bearer of infected germs, begetting in open wounds the fermentative process of suppuration so analogous in all essential features to the putrefaction of animal fluids and solids. His conception was to treat the wound with some substance which, without doing serious mischief to the tissues, would destroy the microbes already contained and prevent the access of others in the living state. For this purpose he selected carbolic acid with which, in solution, he treated the wound, hands, instruments, and every thing which might come in contact with the wound. Regarding the air as the chief source of infecting bacteria, he hoped by a spray of carbolic acid to disinfect the air over and about the field of operation. The dressings applied to the wound were permeated with carbolic acid, and all possible precautions were observed in their arrangement to exclude the air. The very essence of all the great advances in surgery and medicine based on bacteriologic investigations, and which have revolutionized the practice of both medicine and surgery, is contained in this apparently simple induction by Lister. It detracts in no way whatever from the value of his discoveries that advancing knowledge has improved and simplified the methods originally instituted by the founder of antiseptic surgery. The great pivotal fact stands just as Lister worked it out, that infection of wounds is effected from without and is due to micro-organisms acting in an analogous manner to similar forms of life in begetting fermentation and putrefaction, as demonstrated by Pasteur. The mental picture he formed of the difference in

*Presidential Address before the British Association for the Advancement of Science, Liverpool, September 16, 1896.

healing of a simple and compound fracture is as illustrative to-day as in 1867.

As already observed, Lister's early work, though abounding with experimental studies relating to changes produced by bacteria when admitted into blood and milk, was based upon analogies drawn from the relation of bacteria to the processes of fermentation and putrefaction. Almost nothing was known as to the specific character of the bacteria producing suppuration and other processes of wound infection. In 1878 Robert Koch made an epoch in the development of bacteriology, which established a definite scientific basis for the perfection of Lister's ideas. Koch demonstrated that various infectious diseases were caused by specific micro-organisms. Three years later Koch gave to the world the details of his method of isolating and cultivating bacteria in solid transparent media, which made possible the great discoveries of modern bacteriology. Indeed, at this period it may fairly be claimed that the science of bacteriology was born. The studies of Ogston, Rosenbach, and Passet upon the bacteria of suppuration followed, and the pyogenic staphylococci and streptococci were demonstrated. The character and habits of these great enemies of the surgeon, their method of access to wounds, and distribution inside, were studied by observation and experiment. These important deductions were soon made known: First, that atmospheric microbes are mainly of an innocent character as related to wound infection, that the habitat of micro-organisms is upon the surface of ordinary objects and not in the air, and that infection comes from contact. Second, that the fluids and cells of the animal body are capable of disposing of a considerable number of pyogenic bacteria without appreciable injury. The practical application consisted in dispensing with the spray; in concentrating attention toward excluding germs from wounds and in discontinuing the application of strong germicidal agents which destroy the physiologic

resistance of the tissues to germ invasion. These latter observations will be recognized as the rational basis upon which asepsis was established. The perfection of methods of drainage for the double purpose of removing the pabulum most acceptable to germ development, and to prevent tension, belongs to the Listerian system; as does also the use of the animal ligature, which may be readily disposed of by the tissues instead of remaining as an irritant.

These fundamental bacteriologic principles compose the basis of modern surgery. Within a few years standard and classic treatises on surgery were rendered obsolete ; new text books had to be written. The science and art of surgery attained a perfection in practical results surpassing the highest ideals of the surgeons of preceding generations. New departments of surgery were established and regions invaded which were hitherto outside the scope of operative treatment. The science and practice of midwifery were also revolutionized and all former teachings recast. The results are the pride of our profession and the wonder of the latter half of the nineteenth century. The influence of the discovery and classification of the pathogenic bacteria upon surgery can scarcely be appreciated by surgeons themselves without reflection. Indeed, until this time surgery could scarcely be called a science ; it was practiced for the most part as an art.

The great facility of absorption possessed by the peritoneum made abdominal surgery the field of conflict for deciding the comparative merits of asepsis, and the relation of bacteria to wound infection generally. By many the protection assured by sterilization and mechanical cleansing, without chemical germicides, was interpreted as disproving the bacteriologic basis of modern wound treatment. The injurious local effects of chemical germicides became generally recognized in abdominal surgery and these agents were soon eliminated from the technique of this department of surgery. The influence of

abdominal surgeons in promoting aseptic methods to the superseding of antiseptic agents is well known. Moreover, increased experience showed that chemical germicidal agents do not possess the vigor of germ destruction first attributed to them. Much of this confusion was due to the failure to recognize the power of the tissues to resist germ invasion, and that in all surgical operations a certain degree of bacterial infection is overcome by this resistance.

The conflict between the advocates of asepsis and antisepsis was most unfortunate. Reliance upon antiseptics begot a disregard for mechanical cleanliness, and established a confidence in chemical germicides to atone for slovenly methods throughout an operation. Moreover, the profession was slow to recognize that the germicidal power of a chemical agent, as shown by experiment within a small area, is not proportionate when applied to large operative fields. Again, it was some time before it was conceded that such chemicals impair the tissues of wound surfaces and weaken their resistance to microbic invasion.

At this stage of the evolution of modern surgical methods professional opinion was in a state of great confusion and uncertainty. Many leaders of surgical opinion, while practicing asepsis (and this is especially true of the Birmingham school of surgery) derided all bacteriologic discoveries and repudiated germ invasion as the cause of septic infection. This school of surgeons used the term "dirt," and lauded "cleanliness," repudiating the terms "bacteria" and "sterilization." The result was that many practitioners of surgery were misled; confidence in fundamental principles was impaired or destroyed; and only half-hearted efforts of antisepsis and asepsis were put forth. The disastrous results of those times are fresh in the memory of all present. These discussions have now ceased, and throughout all civilized nations, where surgery is taught and practiced as a science, the principles of Lister are accepted and applied.

With the knowledge we now possess as to the relation of micro-organisms to wound infection it might be reasonable to presume from a theoretical standpoint that suppuration and systemic infection should be altogether banished from surgical experience. Indeed, with the precise knowledge derived from bacteriologic investigation as to the pyogenic bacteria, and the demonstrated resources for their destruction and elimination in surgical practice, it might seem that such perfection of technique is practicable as to remove sepsis altogether from the possibilities of elective surgical procedures. This degree of perfection, however, has not yet been attained; and it is doubtful if it ever will be. Suppuration and infection are frequent as complications and sequelæ of surgical operations, and hence no subject more important or practical can engage our attention.

It has been frequently stated that when suppuration supervenes in a wound, deliberately made by the surgeon, through healthy integuments, there has been some avoidable error in the operative technique. While such a standard is justified by bacteriologic demonstration, and should be held up by every conscientious surgeon as a criterion, it can scarcely be attained in practice. The truth of this observation is attested by a cursory glance over the current medical literature of the day. Clinical reports and society discussions abound with deaths attributed to "heart failure," "suppression of urine," "intestinal obstruction," "exhaustion," and other vague causes of death which are in reality due to sepsis. That suppuration in operation wounds is very common is generally known. Such unfortunate results are almost the rule in operations of emergency and in operations hastily carried out in private practice. Under these circumstances, however, no fair test is made of a thorough aseptic technique, and infection is due to the imperfect use of those resources known and applied by operative surgeons. But under conditions where all facilities are at hand,

and where reasonable care is observed, suppuration and infection continue to occur in a considerable proportion of cases. In proof of this latter statement I would cite the words of a master in surgical pathology and operative methods: "I have made it a duty on my part to familiarize myself with the advances made in the technique of aseptic surgery, and have the good fortune to perform all my operations in two of the best hospitals in Chicago and in a fairly well equipped college clinic, and yet I am only too willing to confess that I never finish my day's work without seeing pus. I have a painful recollection of two amputations for carcinoma of the breast on private patients, in both of which every possible precaution was carried out, and yet to my utmost disappointment both of them died of the most virulent form of sepsis I ever encountered. To offset these cases I might refer to perhaps over two hundred similar operations in which, under much less rigid precautions, with few exceptions, faultless wound healing was obtained. I remember, too, a case of genu valgum in an adult treated by transcondyloid osteotomy under strict antiseptic precautions, where the operation was followed by violent suppurative osteomyelitis and extensive necrosis which for a long time seriously threatened the limb and life of the patient. I am sure that I am not alone in relating such experiences."*

Again, as proof that the most complete scientific equipment and environment for operative work, together with experienced and skilled operators and assistants, is not at present an absolute guarantee against sepsis, the following report of Dr. J. C. Clark, of the Gynecological Department of the Johns Hopkins Hospital, is cited: "I recall a hystero-myomectomy in a colored woman which was free from streptococci as shown by cultures taken from the interior of the uterus at the time of the operation. The evening of the day of operation the patient developed a temperature of 105 degrees F. and within the next

* Some of the Limits of the Art of Surgery, by Nicholas Senn, Journal of American Medical Association, May 9, 1896, p. 906.

forty-eight hours died. Cultures from the blood and all of the organs showed myriads of streptococci. The infection was so virulent that the patient had been simply overwhelmed and died of acute toxic symptoms. The peritoneum showed little evidence of serous inflammation, as death had occurred before a marked reaction could be established." *

During the past year, after an unbroken series of sixty-four abdominal sections without a death, I lost a patient after an operation for hysterectomy under identical circumstances to that above related by Dr. Clark. The case was altogether uncomplicated, and the operation presented no unusual difficulties. It was performed in the same operating room, with the same assistants, nurses, and with all the care and protection of the previous operations. A very careful investigation convinced me that the infection could have been conveyed by no other means than my hands.

It is the purpose of this paper, in view of these facts, to invite attention to the several parts of the modern aseptic surgical technique in order to determine the weak places and direct attention to re-enforcing the same. In the first part of this paper I have briefly presented the steps by which our present method of defense against bacterial invasion and its results was established ; that methods of protection based upon these scientific principles of bacteriology have almost eliminated sepsis from the dangers of operations and revolutionized surgical practice is a demonstration of the accuracy and reliability of those principles. That in proportion to the increased precision born of experience with which surgeons work sepsis is lessened is an additional proof of the possibilities of obtaining immunity from sepsis. Whether or not absolute immunity will ever be attained is doubtful ; but a nearer approach to complete immunity must be the aim of surgeons in all time.

In taking up the various parts of the surgical technique with a view to detecting its vulnerable points, we must first direct

* American Journal of Obstetrics, May, 1896, p. 718.

our attention to certain personal characteristics of the surgeon himself. In the first place it is indispensable that one doing surgery should have some knowledge of the character and life history of the micro-organisms with which the surgeon has specially to deal. It will not suffice to have only a vague idea that germs exist which if conveyed into a wound will infect; the surgeon must know something of the habitat and mode of diffusion of these invisible forms of life. Fortunately bacteriologists have so simplified this subject that one can very easily provide himself with all essential knowledge relating to the pyogenic bacteria. He should especially attain such familiarity with the character of these micro-organisms as to realize that their spores offer much greater resistance to germicidal agents than the mother-plant. Moreover, the surgeon must have some high conception of cleanliness in order to establish proper defense against wound infection on the part of himself and of those associated with him. As long as the meaning of personal cleanliness must vary with the individual interpretation of the surgeon, so will any thing like absolute uniformity of results in surgical practice be impossible. And when we come to consider that these same varying features of individuality must obtain in assistants and nurses, we realize how complex and difficult is the apparently simple problem of surgical cleanliness. Indeed, for attaining any thing near perfection in aseptic operative work, the combined efforts of surgeon, assistants, and nurses, endowed naturally with special capacities for individual cleanliness and mastery of details, are essential requisites.

With the improved facilities now at the command of operative surgeons in modern hospitals, protection from infection, in so far as relates to instruments, sponges and their substitutes, dressings, sutures and ligatures, together with operative utensils, such as basins, tables, and other apparatus, may be guaranteed. With the usual methods of mechanical cleansing,

followed by sterilization with boiling water or steam, it is a simple and easy process, if intelligently and faithfully applied, to render these materials free from the possibilities of infection. That it requires care, vigilance, intelligence, and faithful devotion to the work to establish and maintain such perfection of detail every one who has followed the work knows full well; but that in this part of the operative technique absolute immunity from sepsis can be secured there can be no doubt. That part of the operative technique, however, presenting the greatest difficulties relates to the disinfection of the surgeon's hands and those of his assistants.

That this has long been recognized I here quote the classic language of the late Thomas Keith, written twelve years ago: "It is, unfortunately, a melancholy story that ever since surgery began the most of the mischief was done by the surgeon himself. It was the willing and tender, though *unclean*, hand that carried the poison into the wounds." *

Here is undoubtedly the vulnerable point in our armour. When we remember that the surgeon's hands from the nature of things must come daily in contact with pyogenic bacteria in the performance of his varied duties, we must recognize that here lies the greatest peril of wound infection. Moreover, since infection obtains by contact, the surgeon's hands are the most constant medium of germ transmission. It is daily demonstrated that boiling is absolutely destructive to all forms of bacterial life which could possibly infect a wound, but no method yet devised can with such assurance and certainty sterilize the surgeon's hands and the field of operation. It is to the perfection of this part of the operative technique that more care should be given and improved methods should be devised.

It is well known that various micro-organisms are so intimate in their relation to the skin that it is almost impossible to get rid of them. Investigations by competent observers have

* Contributions to the Surgical Treatment of Fibroid Tumors of the Uterus, Edinburgh, 1885.

shown that no matter how rigid the disinfection of the patient's skin, and the cleansing of the operator's hands, the sterilization of instruments, and other precautions exercised, a certain number of wounds in which sutures are employed will suppurate. While these cases are exceptional, bacteriologic investigation demonstrates their possibility as a result of bacteria imbedded in the skin. Welch has described, under the name of staphylococcus epidermidis albus, a micrococcus which seems to be habitually present in the skin, both upon the surface and deep down in the Malpighian layer. He is of the opinion that this micro-organism may, under certain conditions, be a cause of skin-abscesses, regarding it as the same organism commonly present upon the skin and known as the staphylococcus pyogenes albus in an attenuated condition. These organisms are found to be capable of development when removed from the epidermis after the hands have been immersed in a strong solution of bichloride of mercury and other germicidal solutions. Whether or not this form of micrococci is ever the active means of infection after thorough scrubbing and disinfection of the hands is somewhat doubtful, but this observation has shown that the ordinary cleansing and disinfection of the skin with the means now in use are far from perfect. These facts give additional and indubitable evidence of the necessity of devising more perfect methods of skin disinfection.

The limits of this paper prevent that thorough consideration of this particular part of the aseptic surgical technique which its great importance demands, and it is only my purpose to treat a few common-place, but essential, requisites for hand cleansing which all concede to be necessary, but are so constantly and generally neglected. The subject of hand-disinfection in detail is now receiving, and must continue to receive, careful consideration.*

*On the Disinfection of the Hands, by Robert F. Weir, M. D., N. Y. Medical Record, April 3, 1897, p. 469.

I would call attention to the necessity of a surgeon habitually engaged in operative work giving daily and constant attention to his hands, with a view to habitual cleanliness and freedom from abrasions and consequent foci of infection. I am aware that this is frequently mentioned in all treatises on the aseptic surgical technique, and am equally aware that it is not commonly observed. The surgeon's hands should not be soft and tender; they should be accustomed to work, and consequently the skin should be firm and thereby equal to resisting slight injuries. The nails should be kept carefully trimmed, and the spaces thereabout thoroughly cleansed. After making vaginal and other examinations, wherein the hands are brought in contact with discharges, more than a mere hasty washing should be done. They should be thoroughly cleansed with warm water, soap, and brush. If such facilities are not at hand at the moment, they should be obtained as quickly as possible after such examination. Gloves very quickly become infected and may remain indefinitely the medium of renewed infection. In preparing for an operation at least thirty minutes should be reserved for cleansing the hands. The same precautions as to time and detail should be observed in the preparation of the surfaces forming the field of operation. The surface of the body is constantly swarming with micro-organisms, the habits of the individual having much to do with their character. Pus-forming agents are completely protected by the fatty products of the sweat ducts, and the removal of these products along with dead epithelium is essential to any thing like a thorough mechanical cleansing of the skin. The use of soap and hot water, thoroughly applied with brush, followed by a vigorous application of alcohol, ether, or turpentine to remove the fatty products mentioned, should be a preparatory step to the application of chemical disinfection.

After numerous tests with various methods of disinfection for the hands, I have adopted the following which is commended by its simplicity as well as its efficiency:

The hands are first examined as to any abrasions or injuries, and the nails, if too long, carefully pared and the spaces about cleansed with a nail cleaner.

The arms, having been bared above the elbows, the hands and arms are scrubbed with a liberal quantity of green soap with hot water and a stiff brush for ten minutes.

After drying the hands and arms with a towel, the nails and under-lying spaces are again carefully cleansed with the nail cleaner.

Ordinary mustard-flour mixed with warm sterilized water in the hands is applied with friction for five minutes and then washed off with warm sterilized water.

The hands are now thoroughly bathed in strong alcohol (80 per cent).

After putting on an apron or gown, the hands are given a final washing in a stream of warm water running over the hands, brushing them again.

During the operation the tissues exposed should be handled as little as possible. By packing off areas of exposure with sterilized gauze, and avoiding the handling of all parts which are to be left behind, the danger of infection from the hands is much reduced.

The same principles are applied to the cleansing and disinfecting of the patient's skin as are observed in preparing the surgeon's hands. General baths should be given for several days preceding operation whenever possible, and a general bath should closely precede the special preparation of the operative field. Thorough scrubbing of the operative field and adjacent folds of skin with hot water, soap, and brush, using the razor upon hairy surfaces, should be applied two hours prior to the operation. Ether, alcohol, or turpentine should be used to remove all fatty products from the skin, and finally a protecting pad of sterilized gauze should be secured by a bandage to protect the disinfected area. A final cleansing with alcohol and

hot sterilized water should be applied on the operating table after the patient is anesthetized.

The perfection of the operative technique can not be attained through *preparation* of instruments, sponges, ligatures, sutures, hands of operator, of assistants, of nurses, and of field of operations *alone*. There remains the additional requirement of *maintaining throughout the operation* protection of all exposed parts from both direct and indirect routes of infection. There must be a special skill, acquired through training and self-control, which concentrates the operator's mind upon the work before him, and which assures a manual dexterity that holds all the operative field in hand, with directness of purpose and precision of action. No preparation of instruments and apparatus; of sutures, ligatures, and sponges; of hands and field, perfected by sterilization by heat and germicidal solutions, can secure perfection and uniformity in asepsis except it be supplemented by such operative skill as I have endeavored to indicate in this paragraph.